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(54) **ROTARY POWER TOOL**

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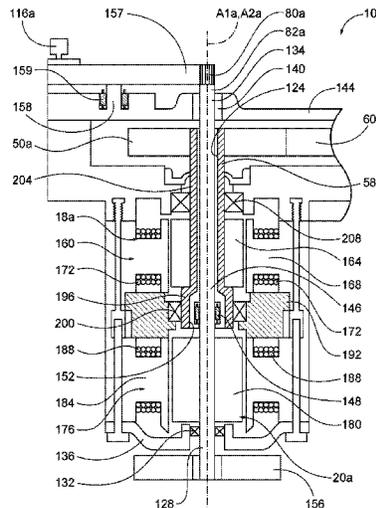
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(57) **ABSTRACT**

A rotary hammer includes a housing, a first motor supported by the housing and defining a first motor axis, a second motor supported by the housing and defining a second motor axis that is coaxial with the first motor axis, and a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate. The rotary hammer further includes a reciprocation mechanism operable to create a variable pressure air spring within the spindle. The reciprocation mechanism includes a piston configured to reciprocate within the spindle in response to receiving torque from the second motor, a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and an anvil that is impacted by the striker when the striker reciprocates towards the tool bit. The anvil imparts axial impacts to the tool bit.

**10 Claims, 6 Drawing Sheets**



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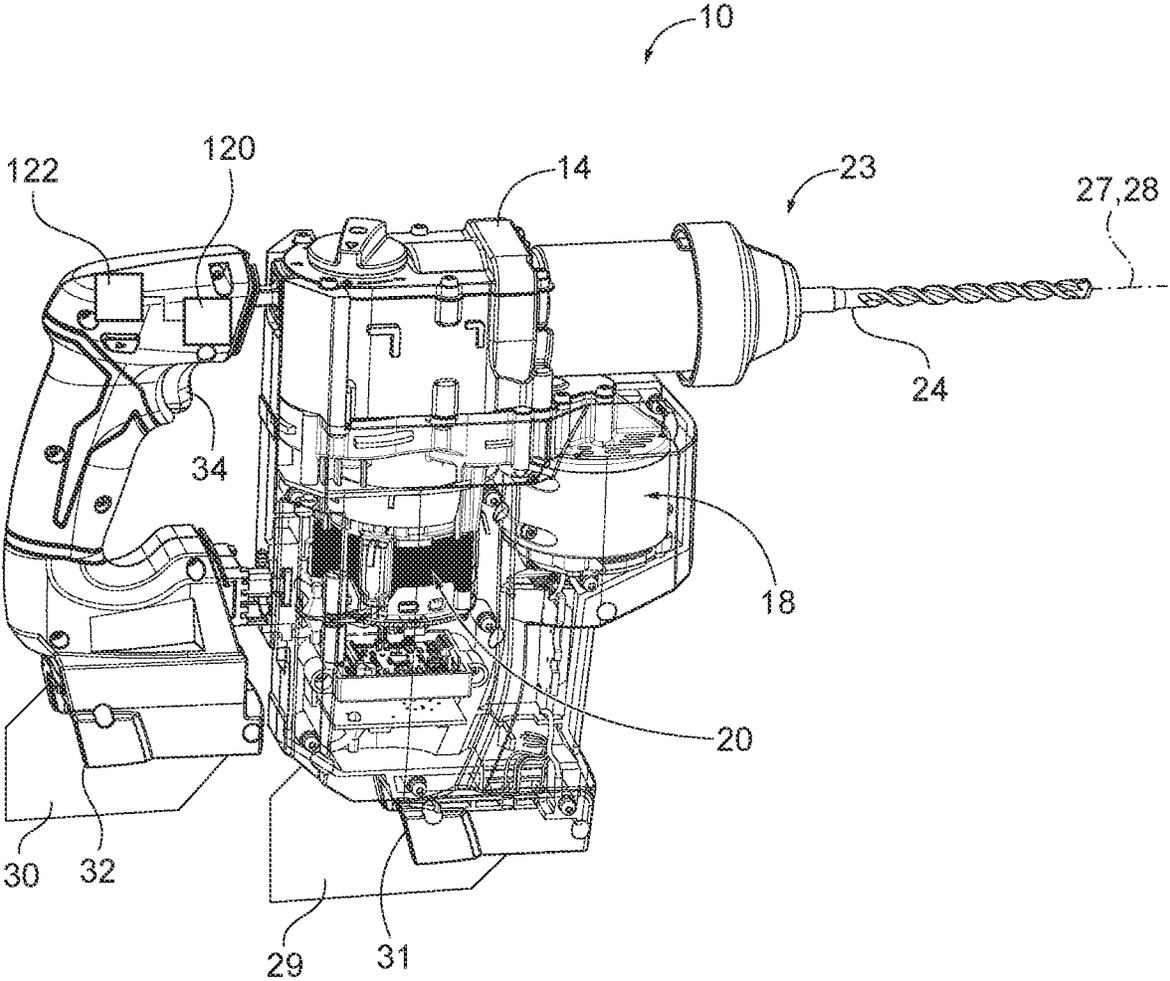


FIG. 1

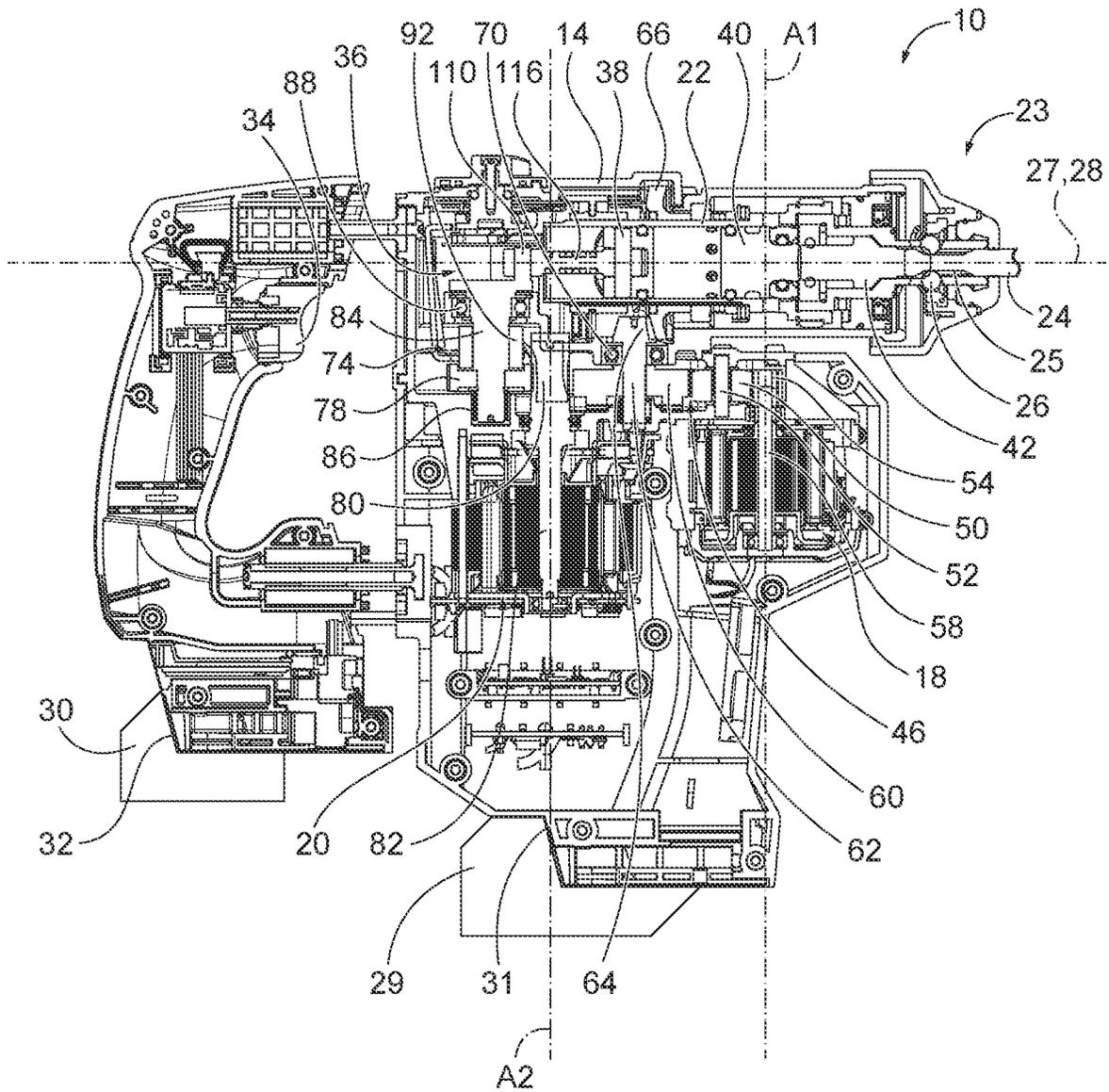


FIG. 2

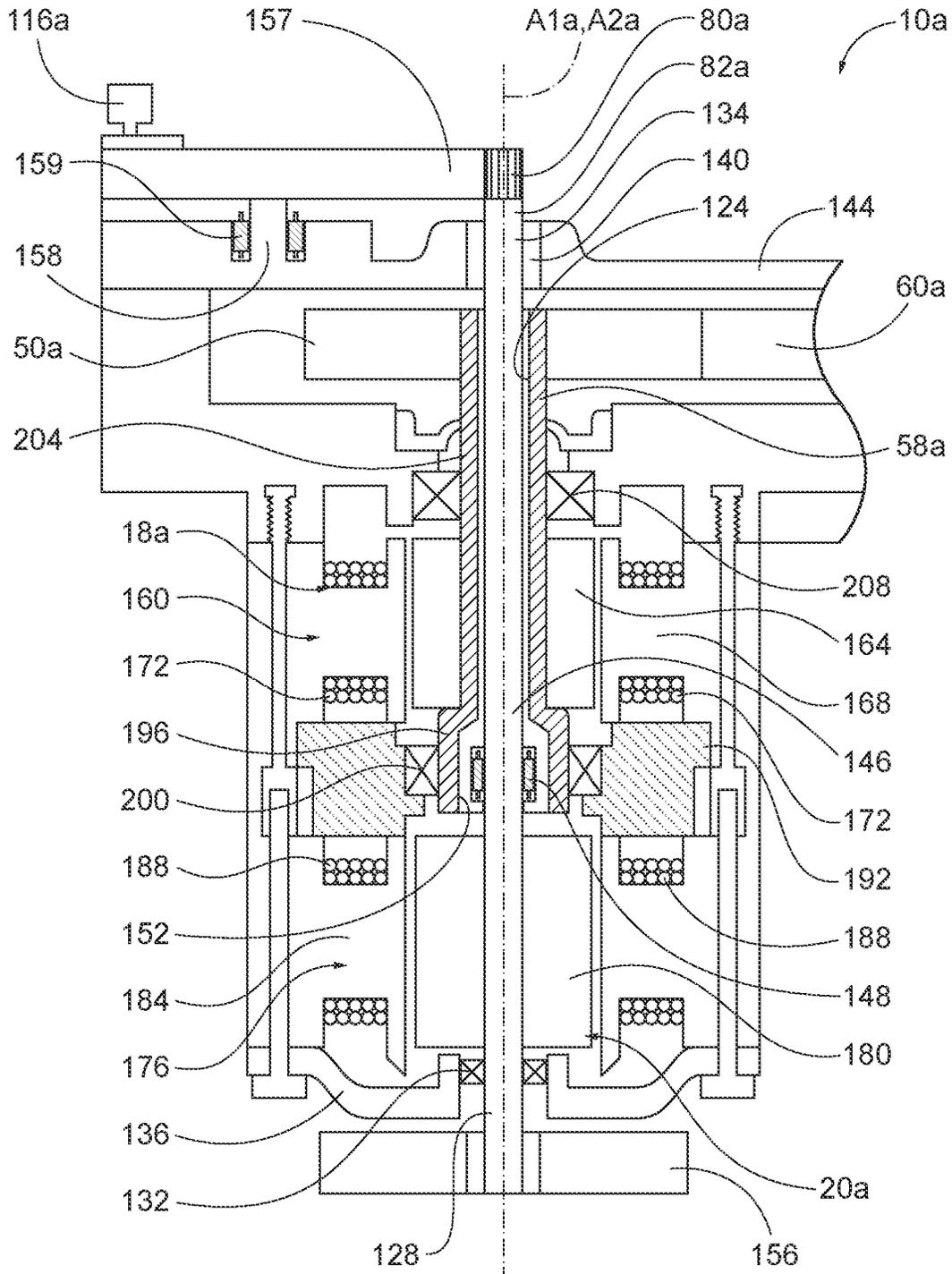


FIG. 3

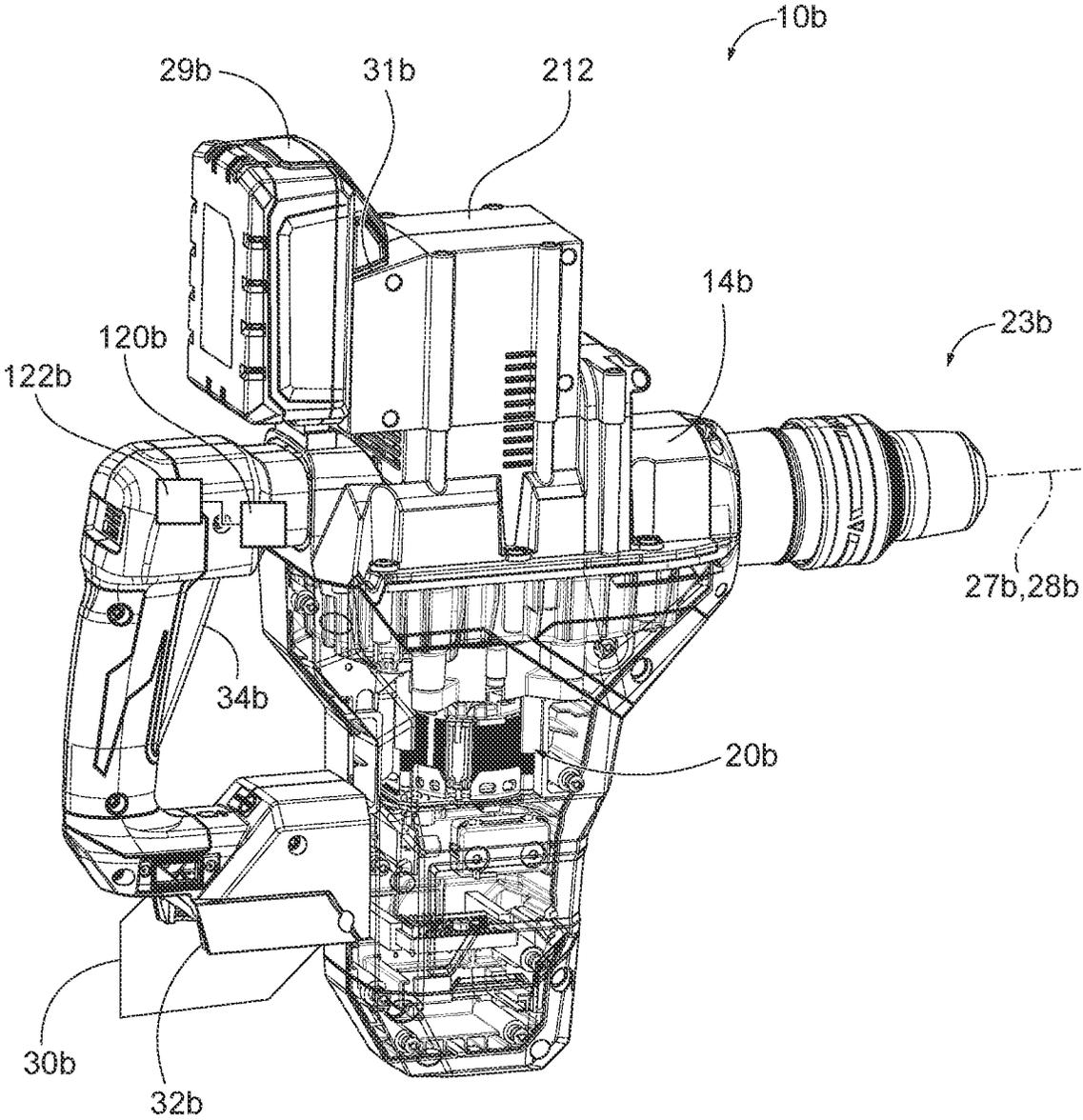


FIG. 4

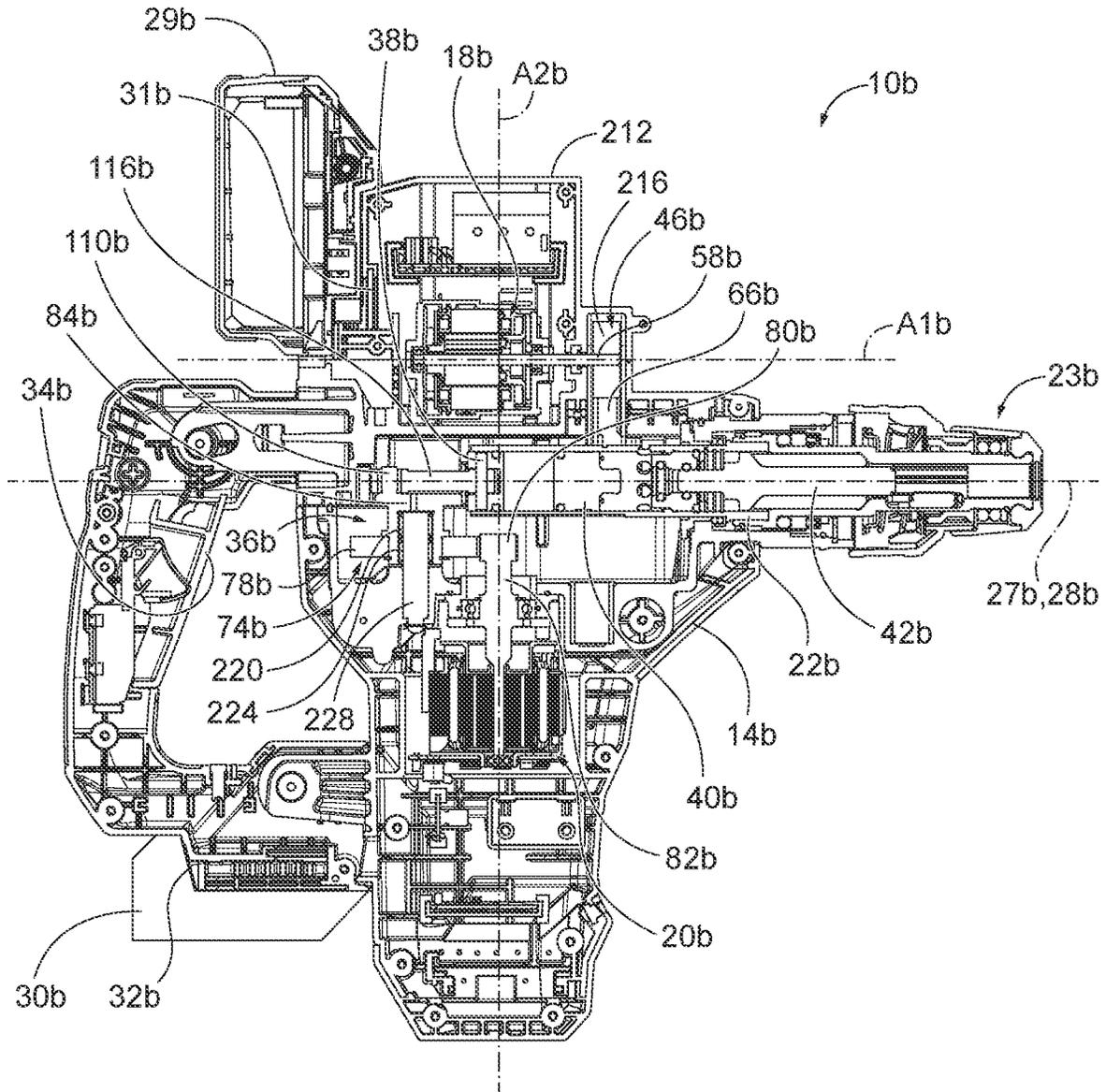


FIG. 5

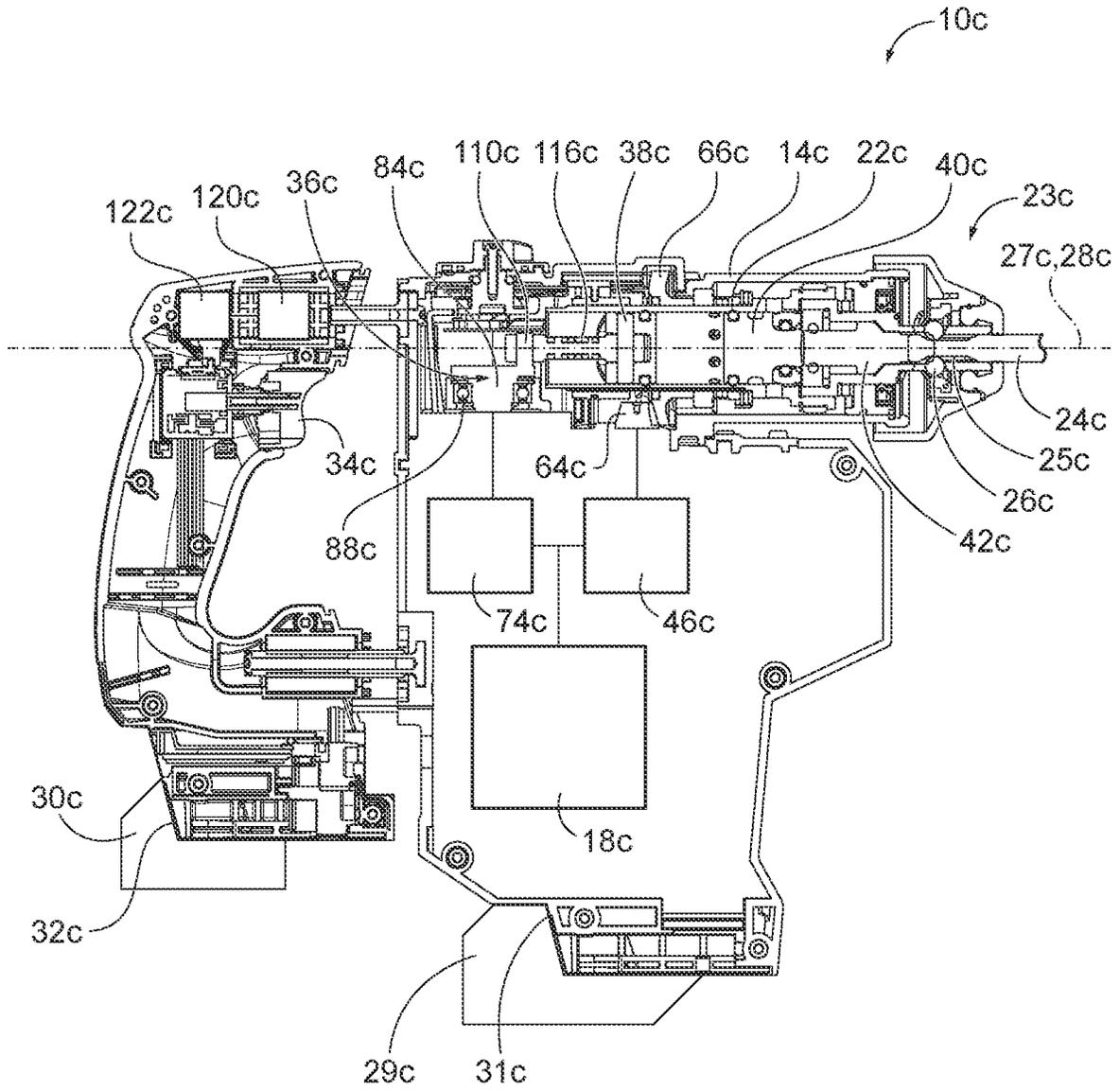


FIG. 6

1

**ROTARY POWER TOOL****CROSS-REFERENCE TO RELATED APPLICATIONS**

This application claims priority to U.S. Provisional Patent Application No. 63/138,852 filed on Jan. 19, 2021, the entire content of which is incorporated herein by reference.

**FIELD OF THE INVENTION**

The present invention relates to rotary power tools, and more particularly to rotary hammers.

**BACKGROUND OF THE INVENTION**

Rotary hammers can include impact mechanism having a reciprocating piston disposed within a spindle, a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and an anvil that is impacted by the striker when the striker reciprocates toward the tool bit. Rotary hammers also transfer torque to the spindle, such that the spindle can rotate the tool bit as it reciprocates in response to reciprocation of the striker.

**SUMMARY OF THE INVENTION**

The present invention provides, in one aspect, a rotary hammer adapted to impart axial impacts to a tool bit. The rotary hammer includes a housing, a first motor supported by the housing and defining a first motor axis, a second motor supported by the housing and defining a second motor axis that is coaxial with the first motor axis, and a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate. The rotary hammer further includes a reciprocation mechanism operable to create a variable pressure air spring within the spindle. The reciprocation mechanism includes a piston configured to reciprocate within the spindle in response to receiving torque from the second motor, a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and an anvil that is impacted by the striker when the striker reciprocates towards the tool bit. The anvil imparts axial impacts to the tool bit.

The present invention provides, in another aspect, a rotary hammer adapted to impart axial impacts to a tool bit. The rotary hammer includes a housing, a first motor supported by the housing and defining a first motor axis, a second motor supported by the housing, and a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate. The spindle defines a rotational axis that is parallel with the first motor axis. The rotary hammer further includes a reciprocation mechanism operable to create a variable pressure air spring within the spindle. The reciprocation mechanism includes a piston configured to reciprocate within the spindle in response to receiving torque from the second motor, a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and an anvil that is impacted by the striker when the striker reciprocates towards the tool bit. The anvil imparts axial impacts to the tool bit.

The present invention provides, in yet another aspect, a rotary hammer adapted to impart axial impacts to a tool bit. The rotary hammer includes a housing, a motor supported by the housing, and a spindle coupled to the motor for receiving torque from the motor, causing the spindle to rotate. The spindle has an adjustable rotation speed. The rotary hammer

2

further comprises a reciprocation mechanism operable to create a variable pressure air spring within the spindle. The reciprocation mechanism includes a piston configured to reciprocate within the spindle in response to receiving torque from the motor. The piston has an adjustable reciprocation frequency. The reciprocation mechanism also includes a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston and an anvil that is impacted by the striker when the striker reciprocates towards the tool bit. The anvil imparts axial impacts to the tool bit. The rotary hammer further comprises a first transmission configured to transfer torque from the motor to the spindle and a second transmission configured to transfer torque from the motor to the reciprocation mechanism. The reciprocation frequency of the piston is adjustable independent of the rotation speed of the spindle. The rotation speed of the spindle is adjustable independent of the reciprocation frequency of the piston. At least one of the first and second transmissions is a multi-speed transmission.

Other features and aspects of the invention will become apparent by consideration of the following detailed description and accompanying drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a perspective view of a rotary hammer according to an embodiment of the invention.

FIG. 2 is a cross-sectional view of the rotary hammer of FIG. 1.

FIG. 3 is an enlarged, cross-sectional view of a rotary hammer according to another embodiment of the invention.

FIG. 4 is a perspective view of a rotary hammer according to another embodiment of the invention.

FIG. 5 is a cross-sectional view of the rotary hammer of FIG. 4.

FIG. 6 is a cross-sectional view of a rotary hammer according to another embodiment of the invention.

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

**DETAILED DESCRIPTION**

FIGS. 1 and 2 illustrate a rotary power tool, such as rotary hammer 10, according to an embodiment of the invention. The rotary hammer 10 includes a housing 14, first and second motors 18, 20 disposed within the housing 14, and a rotatable spindle 22 coupled to the first motor 18 for receiving torque from the first motor 18. The first motor 18 defines a first motor axis A1 that is parallel with a second motor axis A2 that is defined by the second motor 20. In the illustrated embodiment, the rotary hammer 10 includes a quick-release chuck 23 coupled for co-rotation with the spindle 22 to facilitate quick removal and replacement of different tool bits. A tool bit 24 includes a necked section 25 or a groove in which a detent member 26 of the quick-release chuck 23 is received to constrain axial movement of the tool bit 24 to the length of the necked section 25 or groove. The rotary hammer 10 defines a tool bit axis 27,

which in the illustrated embodiment is coaxial with a rotational axis **28** of the spindle **22**.

The first and second motors **18, 20** are configured as DC motors that receive power from on-board power sources, such as first and second battery packs **29, 30** that are respectively selectively coupled to first and second receptacles **31, 32** on the housing **14**. In some embodiments, only the first battery pack **29** is coupled to the first receptacle **31**, and the first and second motors **18, 20** both receive power from the first battery pack **29**. In other embodiments, only the second battery pack **30** is coupled to the second receptacle **32** and the first and second motors **18, 20** both receive power from the second battery pack **30**. In other embodiments, the first and second battery packs **29, 30** are both respectively coupled to the first and second receptacles **31, 32**, and the first motor **18** receives power from the first battery pack **29**, and the second motor **20** receives power from the second battery pack **30**.

The first and second battery packs **29, 30** may include any of a number of different nominal voltages (e.g., 12V, 18V, etc.), and may be configured having any of a number of different chemistries (e.g., lithium-ion, nickel-cadmium, etc.). Alternatively, the first and second motors **18, 20** may be powered by a remote power source (e.g., a household electrical outlet) through a power cord. The first and second motors **18, 20** are selectively activated, either simultaneously or separately as described in further detail below, by depressing an actuating member, such as a trigger **34**.

The rotary hammer **10** further includes an impact mechanism **36** (FIG. 2) having a reciprocating piston **38** disposed within the spindle **22**, a striker **40** that is selectively reciprocable within the spindle **22** in response to reciprocation of the piston **38**, and an anvil **42** that is impacted by the striker **40** when the striker reciprocates toward the tool bit **24**. Torque from the first motor **18** is transferred to the spindle **22** by a first transmission **46**. In the illustrated embodiment of the rotary hammer **10**, the first transmission **46** includes a first gear **50** rotatable on a stationary shaft **52** and engaged with a pinion **54** on an output shaft **58** that is selectively driven by the first motor **18**. The first transmission **46** further includes a second gear **60** in meshing relationship with the first gear **50**, and a drive shaft **62** coupled for rotation with the second gear **60** and having an drive pinion **64** engaged with and configured to drive an output gear **66** coupled for co-rotation with the spindle **22**. The drive shaft **62** is rotatably supported within the housing **14** by a bearing **70** arranged between the second gear **60** and the drive pinion **64**. The output gear **66** is secured to the spindle **22** using a spline-fit or a key and keyway arrangement, for example, that facilitates axial movement of the spindle **22** relative to the output gear **66** yet prevents relative rotation between the spindle **22** and the output gear **66**.

The impact mechanism **36** is driven by a second transmission **74** that receives torque from the second motor **20**. The second transmission **74** includes an input gear **78** that is engaged with a pinion **80** on an output shaft **82** that is selectively driven by the second motor **20**. The impact mechanism **36** includes a crankshaft **84** that is coupled for co-rotation with the input gear **78** and is rotatably supported within the housing **14** by bearings **86, 88** and a bushing **92**. The crankshaft **84** includes an eccentric pin **110** and the impact mechanism **36** further includes a connecting rod **116** interconnecting the piston **38** and the eccentric pin **110**.

With reference to FIG. 1, the rotary hammer **10** includes a mode selection switch illustrated schematically at **120** in electrical communication with the first and second motors **18, 20**, to allow an operator to switch between three modes.

Both of the first and second motors **18, 20** are activated by a controller **122** (also illustrated schematically) in response to the trigger **34** being depressed and the mode selection switch **120** being set to a “hammer-drill” mode, to simultaneously and respectively rotate the spindle **22** and reciprocate the piston **38**. Only the first motor **18** is activated by the controller **122** in response to depression of the trigger **34** and the mode selection switch **120** being set to a “drill-only” mode, such that the spindle **22** is rotated by the motor **18** while second motor **20** is deactivated and the piston **38** is thus inactive. Only the second motor **20** is activated by the controller **12** in response to the trigger **34** being depressed and the mode selection switch **120** being set to a “hammer-only” mode, such that the piston **38** is reciprocated while the first motor **18** is deactivated, such that the spindle **22** does not rotate.

In operation, if “hammer-drill” mode is selected with the mode selection switch **120** and the trigger **34** is depressed, both of the first and second motors **18, 20** are activated. In response to activation of the first motor **18**, rotation of the pinion **54** of the output shaft **58** causes the first gear **50** to rotate. Rotation of the first gear **50** causes the second gear **60** and thus the drive shaft **62** to rotate, such that the drive pinion **64** drives the output gear **66** on the spindle **22**, causing the spindle **22** and the tool bit **24** to rotate. In response to activation of the second motor **20**, the input gear **78** is rotated by the pinion **80**, such that the crankshaft **84** and thus the eccentric pin **110** are rotated as well. Rotation of the eccentric pin **110** causes the piston **38** to reciprocate within the spindle **22** via the connecting rod **116**, which causes the striker **40** to impart axial blows to the anvil **42**, which in turn causes reciprocation of the tool bit **24** against a workpiece. Specifically, a variable pressure air pocket (or an air spring) is developed between the piston **38** and the striker **40** when the piston **38** reciprocates within the spindle **22**, whereby expansion and contraction of the air pocket induces reciprocation of the striker **40**. The impact between the striker **40** and the anvil **42** is then transferred to the tool bit **24**, causing it to reciprocate for performing work on workpiece.

In operation, if “drill-only” mode is selected with the mode selection switch **120** and the trigger **34** is depressed, only the first motor **18** is activated by the mode selection switch **120**, such that the spindle **22** is rotated by the motor **18** while second motor **20** is deactivated and the piston **38** is thus inactive. In operation, if “hammer-only” mode is selected with the mode selection switch **120** and the trigger **34** is depressed, only the second motor **20** is activated by the mode selection switch **120** in response to depression of the trigger **34**, such that the piston **38** is reciprocated, while the first motor **18** is deactivated, such that the spindle **22** does not rotate.

Advantageously, by using first and second motors **18, 20** to respectively and separately control rotation of the spindle **18** and reciprocation of the piston **38**, the reciprocation frequency of the piston **38** may be controlled independently of the rotational speed of the spindle **22**. In other words, the rotational speed of the spindle **22** may be kept constant by keeping the speed of the first motor **18** constant, while the reciprocation frequency of the piston **38** may be increased or decreased by increasing or decreasing the speed of the second motor **20**. By adjusting the reciprocation frequency of the piston **38**, the blow pattern of the tool bit **24** may conveniently be adjusted independent of the rotational speed of the spindle **22**, before or during the operation, depending on a size, cutter, or geometry of the tool bit **24**. Thus, a ratio of the rotational speed of the spindle **18** to the reciprocation

frequency of the piston **38** can be optimized to allow the tool bit **24** to drill at an optimal, maximum speed for a certain operation type.

FIG. 3 illustrates a rotary hammer **10a** according to another embodiment of the invention. The rotary hammer **10a** is identical to the rotary hammer **10**, with like parts having the same annotation plus the letter “a”, and the following differences explained below. In the rotary hammer **10a**, the first motor axis **A1a** is coaxial with the second motor axis **A2a**, and the output shaft **82a** of the second motor **20a** extends through a bore **124** in the output shaft **58a** of the first motor **18a**. A first end **128** of the output shaft **82a** of the second motor **20a** is rotatably supported by a first bearing **132** arranged within a heat sink **136**. An opposite, second end **134** of the output shaft **82a** of the second motor **20a** is rotatably supported by a second bearing **140** arranged within a gearcase **144**. An intermediate portion **146** of the output shaft **82a** of the second motor **20a** is rotatably supported within the output shaft **58a** of the first motor **18a** by a bearing **148** set in a bearing pocket **152** of the output shaft **58a**. A first fan **156** is coupled for rotation with the first end **128** of the output shaft **82a** to axially draw a cooling airflow through the first and second motors **18a**, **20a** during operation. Instead of being engaged with an input gear, the pinion **80a** of the output shaft **82a** of the second motor **20a** is engaged with a driven gear **157** having the eccentric pin **116a**, such that in response to rotation of the output shaft **82a** of the second motor **20a**, the driven gear **157** is rotated by the pinion **80a**. The driven gear **157** includes a stem **158** that is rotatably supported within the gearcase **144** by a bearing **159** set in the gearcase **144**. Instead of being arranged on a stationary shaft, the first gear **50a** is arranged on the first output shaft **58a**.

The first motor **18a** includes a first stator **160** and a first rotor **164** to which the output shaft **58a** of the first motor **18a** is coupled for rotation. The first stator **160** includes a first stator core **168** around which a plurality of first windings **172** are wrapped. In response to activation of the first motor **18a**, electrical current passes through the first windings **172**, thus generating a first electromagnetic field that causes rotation of the first rotor **164**. The second motor **20a** includes a second stator **176** and a second rotor **180** to which the output shaft **82a** of the second motor **20a** is coupled for rotation. The second stator **176** includes a second stator core **184** around which a plurality of second windings **188** are wrapped. In response to activation of the second motor **20a**, electrical current passes through the second windings **188**, thus generating a second electromagnetic field that causes rotation of the second rotor **180**. By arranging the first and second motors **18a**, **20a** to have coaxial axes **A1a**, **A2a**, and by arranging the output shaft **82a** of the second motor **20a** within the output shaft **58a** of the first motor **18a**, the design envelope for the rotary hammer **10a** is advantageously reduced, thus making the rotary hammer **10a** easier to use and store.

In the embodiment illustrated in FIG. 3, the first and second stators **160**, **176** are separated by an intermediate member **192** that includes electromagnetic shielding (e.g., a brass ring) to inhibit the first electromagnetic field generated by the first windings **172** from affecting rotation of the second rotor **180**, and to inhibit the second electromagnetic field generated by the second windings **188** from affecting rotation of the first rotor **164**. Thus, in “hammer-drill” mode, when both of the first and second motors **18a**, **20a** are simultaneously activated, activation of the first motor **18a** does not affect or interfere with operation of the impact mechanism **36a** (not shown in FIG. 3), and activation of the

second motor **20a** does not affect or interfere with rotation of the spindle **22a** (not shown in FIG. 3). In other embodiments, the first and second stator cores **168**, **184** may be formed together, but electromagnetic shielding is still arranged between the first windings **172** and second windings **188**.

A first portion **196** of the output shaft **82a** of the second motor **20a** is rotatably supported by a bearing **200** arranged in the intermediate member **192**. An opposite second portion **204** of the output shaft **82a** of the second motor **20a**, is rotatably supported by a bearing **208** arranged in the gearcase **144**. In some embodiments, a second fan is arranged on the output shaft **82a** of the second motor **20a** between the second rotor **180** and the bearing **208**.

In other embodiments, the first rotor **164** is arranged on top of the second rotor **180** via bearing elements and the second rotor **180** uses the first rotor **164** as a mount. In such an embodiment, the first and second stators **160**, **176** are formed as a single staged stator with separate first and second windings **172**, **188**.

FIGS. 4 and 5 illustrate a rotary hammer **10b** according to another embodiment of the invention. The rotary hammer **10b** is identical to the rotary hammer **10**, with like parts having the same annotation plus the letter “b”, and the following differences explained below. The housing **14b** includes an upper housing portion **212** in which the first motor **18b** is arranged and on which the first receptacle **31b** is arranged. The first motor axis **Alb** is parallel with the rotational axis **28b** of the spindle **22b**. And, a drive gear **216** on the output shaft **58b** of the first motor **18b** is engaged with the output gear **66b**. The crankshaft **84b** is rotatably supported within the housing **14b** by a pair of bearings **220**, **224** set on a stationary post **228**. Advantageously, instead of having to use spiral bevel gears **64**, **66** as in the rotary hammer **10**, in the rotary hammer **10b**, drive gear **216** is a spur gear and output gear **66b** is a spur gear, thus reducing cost. Also, by positioning the first motor **18b** on the opposite side of the rotational axis **28b** of the spindle **22b** as the second motor **20b**, the length of the rotary hammer **10b** (measured along the axis **28b**) is reduced compared to the rotary hammer **10**.

FIG. 6 illustrates a rotary hammer **10c** according to another embodiment of the invention. The rotary hammer **10c** is identical to the rotary hammer **10**, with like parts having the same annotation plus the letter “c”, and the following differences explained below. The rotary hammer **10c** does not have a second motor or second receptacle for a second battery. Rather, in rotary hammer **10c**, the schematically illustrated first motor **18c** provides torque to each of the schematically illustrated first and second transmissions **46c**, **74c**. And, the first and transmissions **46c**, **74c** are both multi-speed transmissions, such as a continuously variable transmission (“CVT”) or an intelligent variable transmission (“IVT”). A CVT is an automatic transmission that can change seamlessly through a continuous range of gear ratios, in contrast with other transmissions that provide a limited number of gear ratios in fixed steps. Similar to a CVT, an IVT performs continuous shifts, correlating to a broader ratio of operation than many other, similar transmissions. Thus, just as in the previous embodiments of the rotary hammers **10**, **10a**, and **10b**, in the rotary hammer **10c**, the first and second transmissions **46c**, **74c** are used to respectively and separately control the rotational speed of the spindle **18c** and the frequency of reciprocation of the piston **38c**.

Although the invention has been described in detail with reference to certain preferred embodiments, variations and

modifications exist within the scope and spirit of one or more independent aspects of the invention as described.

Various features of the invention are set forth in the following claims.

What is claimed is:

1. A rotary hammer adapted to impart axial impacts to a tool bit, the rotary hammer comprising:

- a housing;
- a first motor supported by the housing and defining a first motor axis;
- a second motor supported by the housing and defining a second motor axis that is coaxial with the first motor axis;
- a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate;
- a reciprocation mechanism operable to create a variable pressure air spring within the spindle, the reciprocation mechanism including
  - a piston configured to reciprocate within the spindle in response to receiving torque from the second motor,
  - a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and
  - an anvil that is impacted by the striker when the striker reciprocates towards the tool bit, the anvil imparting axial impacts to the tool bit,
- wherein the first motor includes a first motor output shaft, wherein the second motor includes a second motor output shaft, and wherein the second motor output shaft extends through a bore in the first motor output shaft.

2. The rotary hammer of claim 1, further comprising a bearing disposed within the first motor output shaft, and wherein the second motor output shaft is rotatably supported relative to the first motor output shaft by the bearing.

3. The rotary hammer of claim 1, further comprising electromagnetic shielding disposed between the first motor and the second motor.

4. The rotary hammer of claim 3, wherein the first motor includes a first stator core having first windings, wherein the second motor includes a second stator core having second windings, and wherein the electromagnetic shielding is disposed between the first windings and the second windings.

5. The rotary hammer of claim 3, wherein the first motor includes a first stator core, wherein the second motor includes a second stator core, and wherein the first stator core and the second stator core are formed together as a single staged stator.

6. The rotary hammer of claim 5, wherein the single staged stator includes first windings corresponding to the first stator core and second windings corresponding to the second stator core.

7. A rotary hammer adapted to impart axial impacts to a tool bit, the rotary hammer comprising:

- a housing;
- a first motor supported by the housing and defining a first motor axis;

a second motor supported by the housing and defining a second motor axis that is coaxial with the first motor axis;

electromagnetic shielding disposed between the first motor and the second motor

a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate;

a reciprocation mechanism operable to create a variable pressure air spring within the spindle, the reciprocation mechanism including

- a piston configured to reciprocate within the spindle in response to receiving torque from the second motor,
- a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and

an anvil that is impacted by the striker when the striker reciprocates towards the tool bit, the anvil imparting axial impacts to the tool bit,

wherein the first motor includes a first stator core having first windings, wherein the second motor includes a second stator core having second windings, and wherein the electromagnetic shielding is disposed between the first windings and the second windings.

8. A rotary hammer adapted to impart axial impacts to a tool bit, the rotary hammer comprising:

- a housing;
- a first motor supported by the housing and defining a first motor axis;
- a second motor supported by the housing and defining a second motor axis that is coaxial with the first motor axis;

electromagnetic shielding disposed between the first motor and the second motor;

a spindle coupled to the first motor for receiving torque from the first motor, causing the spindle to rotate;

a reciprocation mechanism operable to create a variable pressure air spring within the spindle, the reciprocation mechanism including

- a piston configured to reciprocate within the spindle in response to receiving torque from the second motor,
- a striker that is selectively reciprocable within the spindle in response to reciprocation of the piston, and

an anvil that is impacted by the striker when the striker reciprocates towards the tool bit, the anvil imparting axial impacts to the tool bit,

wherein the first motor includes a first stator core, wherein the second motor includes a second stator core, and wherein the first stator core and the second stator core are formed together as a single staged stator.

9. The rotary hammer of claim 8, wherein the single staged stator includes first windings corresponding to the first stator core and second windings corresponding to the second stator core.

10. The rotary hammer of claim 9, wherein the electromagnetic shielding is disposed between the first windings and the second windings.